[Proc. Roy. Soc. Victoria, 56 (N.S.), Pt. II., 1945.]

Art. IX.—*The Mesozoic Stratigraphy of the Fly River Headwaters, Papua.*

By N. OSBORNE.

(Published by permission of the Directors of Island Exploration Company Pty. Ltd.)

[Read 9th December, 1943; issued separately 30th June, 1945.]

Abstract.

The headwaters of the Fly River, known to the local natives as Wok Feneng, expose a thick section of Mesozoic sediments in a south dipping monocline on the rugged southern fall of the Central Highlands of New Guinea. These underlie, without apparent angular discordance, the Tertiary limestones supporting the rough mountain ranges or "Limestone Barrier" along the foot of the Central Highlands in western Papua.

The Mesozoic section totalling nearly 7,500 feet of marine sediments is divided on lithological grounds into two distinct units of sedimentation, each dominantly argillaceous at the top and arenaceous at the bottom. These two units have been named Feing and Kuabgen groups respectively. Both are fossiliferous and an examination of the fossils by Dr. M. F. Glaessner establishes the age of the Feing group as Cretaceous (Cenomanian-Albian) and of the Kuabgen group as Upper Jurassic.

The character of the basal Kuabgen rocks suggests a derivation from granitic basement which probably underlies them at no great depth. The time break between the Kuabgen and Feing groups, together with the composition of the basal Feing deposits suggests an Albian transgression over the uppermost Jurassic. An important unconformity is indicated also between the Feing group and the Tertiary limestones by another big time break and a sudden and complete change in lithology.

Introduction.

The object of this paper is to describe the occcurrence of Mesozoic sediments in the headwaters area of the Fly River, referred to hereafter as the Feneng area, to give an account of the section exposed and to indicate its significance in respect to the Mesozoic geological history of New Guinea.

The Fly River rises in the Central Highlands of New Guinea in Papuan territory about 40 miles from the boundary with Netherlands New Guinea and very close to the Mandated Territory border. The main headwaters stream is called by the local natives, Wok Feneng, Wok being the native word for water. The principal tributaries of the Fly are the Alice River (Ok Tedi) to the west and the Palmer and Strickland Rivers to the east.

In this area a series of extremely rough precipitous limestone mountains rises along the foot of the Central Highlands, to be breached in deep narrow gorges by the Fly River and many of its larger tributaries. This "Limestone Barrier" has presented a formidable obstacle to exploration of the main divide.

Karius and Champion (1929) were the first to negotiate these limestones when they crossed the Central Highlands from the Fly to the Sepik River in 1927-8 but they made no observations of stratigraphic value.

Earlier explorations failed to penetrate the Limestone Barrier, but samples collected from the upper Alice River by Austin (1923) and examined by Chapman (1925), and from the Wai Mungi (1924-5), indicated the limestones to be of Tertiary age; while Everill in 1884 found in the Strickland River or one of its tributaries at a point which has since eluded identification, fossils recognized by Wilkinson (1888) to be Cretaceous. [Further study by Dr. Glaessner and writer of Everill's record and comparison of his map with the recently compiled air photographic maps of Island Exploration Coy. indicate that the farthest point reached by his expedition was in the main Strickland River some 3-4 miles below the junction with the Murray River. The locality referred to by Wilkinson as the source of the Cretaceous fossils he identified, is now recognized as one in which very fossiliferous late Tertiary rocks outcrop, indicating that the Cretaceous specimens were not found in situ.]

Downstream from the outcropping limestones Everill also found waterworn pebbles containing ammonites determined by Etheridge (1890) to be Jurassic in age. Probably based on this discovery, Stanley (1923) and later David (1932) show on their maps a patch of Jurassic on this river around latitude 6-7° south. Field investigations by geologists attached to Island Exploration Company 1938-9 have shown that no Mesozoic rocks outcrop south of the Limestone Barrier and that the pebbles found by Everill must have been brought down by the swiftly flowing waters from some locality considerably further upstream. Likewise incorrect are the Mesozoic outcrops shown to occur on the Palmer River below its confluence with the Tully River, extending across to the Fly, and based apparently on stream pebbles picked up by Sir William McGregor and determined by Gregory and Trench (1916).

In 1937 a gold prospecting expedition headed by Ward Williams investigated some of the Fly, Strickland, and Sepik headwaters, and in the upper Om River one of the headstreams of the Strickland, they discovered "black shales studded with magnificent ammonites."—Campbell (1938). Specimens of these ammonites handed to Dr. W. Chawner of Island Exploration Coy. were sent to Dr. Reeside of the U.S. Geological Survey who reported (personal communication) that they are Perisphinctids, indicative of an upper Jurassic or lower Cretaceous age. W. Korn, J. Burke, and W. Kienzle, members of the expedition travelled overland to the Central Highlands by way of the Fly River route and the Wok Kup but have not made available any maps or notes of their journey.

Geologists of Island Exploration Coy. investigating the petroleum possibilities of the Fly River region also found the limestone mountains a serious obstacle to the exploration required to complete the stratigraphic section. Air reconnaissance had shown that the limestone belt was succeeded to the north by an entirely different terrain and that in the main Fly River headwaters (Wok Feneng) and Strickland valley at least, south dipping monoclinal conditions of considerable extent gave promise that good sections of the pre-limestone strata might be exposed there.

Since transport in this remote and mountainous country was confined to native carriers, the difficulty in keeping geological parties beyond the Limestone Barrier supplied sufficiently to remain out long enough to perform useful work was one that could be solved only by the introduction of air transport. Consequently it was decided to send specially equipped expeditions into the upper reaches of both the Fly and Strickland Rivers, and to supply them with foodstuffs by dropping from the air at their most forward bases. It was decided also to send an expedition into the Upper Palmer River although the geology appeared from the air to be complicated by faulting. Here, however, the Limestoue Barrrier is not so strongly developed and it is possible to employ native canoes for transport much closer to the area to be examined, thus obviating the necessity for air transport the success of which depends on clear weather, a condition not frequently fulfilled in this country. The months of December and January were chosen as the period of the year most likely to provide good weather.

The upper Palmer expedition was made in October-November, 1938, under the leadership of Dr. W. Chawner with W. D. Mott as assistant geologist. They measured and described some 3,450 feet of section which they considered unconformably underlies the Tertiary limestone, the upper part of the section being predominantly argillaceous, the lower arenaceous. The contained fossils were examined by Dr. M. F. Glaessner, company palaeontologist, who regarded them as indicating a Cretaceous (Cenomanian-Albian) age.

The Strickland expedition under G. Barrow, December, 1938, and January, 1939, ascended that river with great difficulty to a point some 16 miles above Murray Junction without getting out of Tertiary strata and was prevented by supply troubles from penetrating further.

The Wok Feneng Expedition.

The upper Fly expedition, known as the Wok Feneng Expedition, led by the author with the late G. Sadler, assistant geologist, E. Ross and R. Ely, field assistants, and 70 Papuan natives.

started November 27th, 1938, from a base on the Palmer River, 12 miles above its junction with the Fly River and the limit of water transport convenient to the expedition. The author had made an air reconnaissance with Dr. Washington Gray a few days previously with the object principally of selecting a suitable locality for establishing a base beyond the Limestone Barrier for dropping supplies.

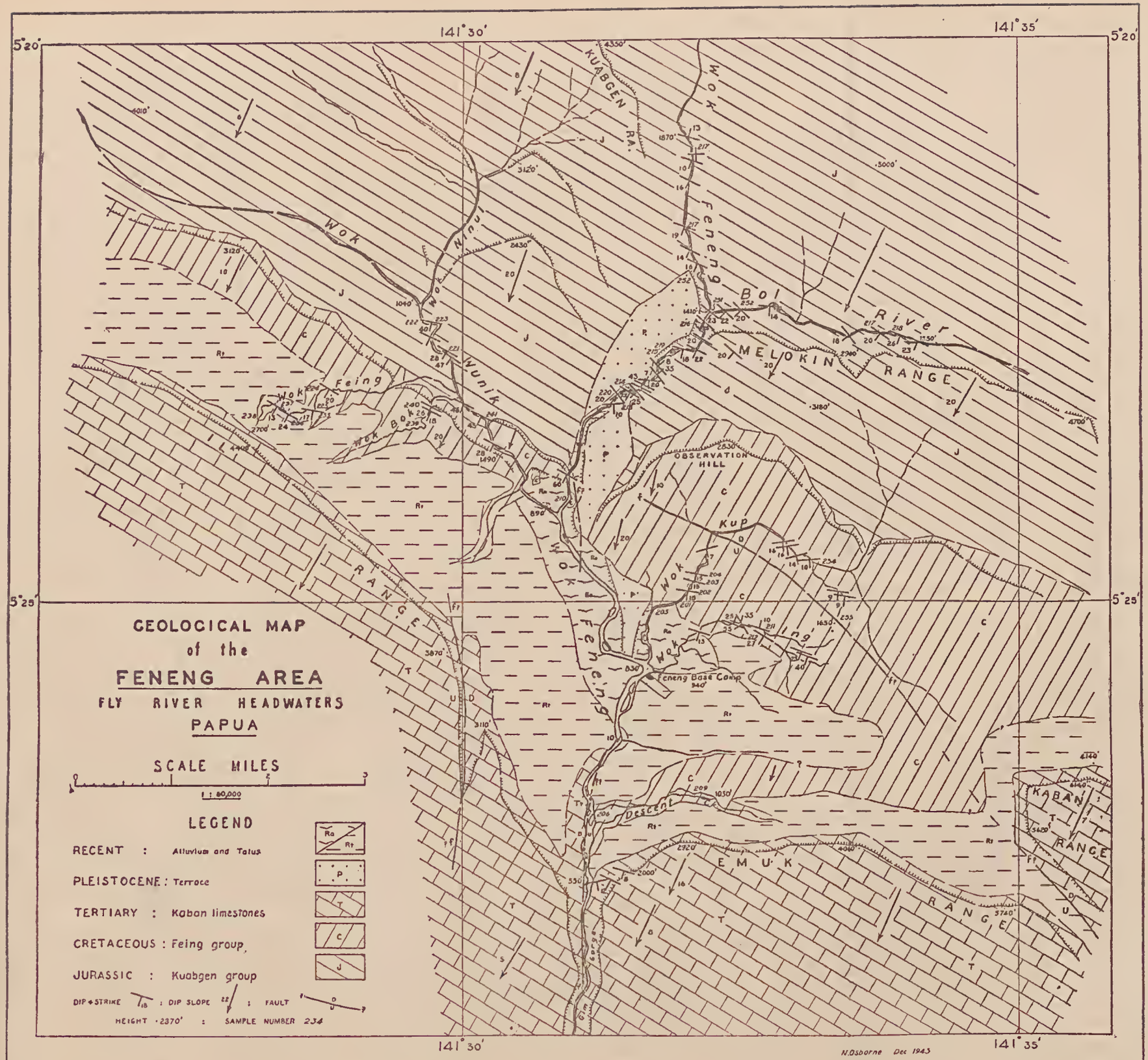
There is no native track across the limestones here and the route followed was roughly that taken by Korn, Burke, and Kienzle along the lip of the Fly River gorge on the east side.

The selected dropping base on the Wok Feneng at its junction with the Wok Kup and Wok Ing was reached December 16th, the journey of 30 miles taking 20 days, adequate testimony to the difficult nature of the country which makes it necessary to relay supplies and equipment in short stages. Base camp was established here and all labour set to work immediately to cut a clearing in the jungle for dropping supplies. This was the Feneng Base Camp.

On arrival the party had enough food to allow the supply aeroplane seven days' grace on its scheduled date of arrival—December 22nd—and then in case of failure, enough to make a five days' return to the forward base on the south side of the Limestone Barrier. Fortunately the weather was fine December 23rd and 24th, and enough food was dropped and recovered to give the party a total of six weeks in the Feneng area.

Except for a small scale air sketch map by Campbell (*ibid.*) and the journey of Korn, Burke, and Kienzle, about which there was no record, the Feneng area was previously quite unexplored and unmapped. The party therefore had to make its own topographic as well as geological survey. It had been intended originally to fix the position of the Feneng Base Camp by astronomic observation using a theodolite and wireless time. However the portable radio set went out of commission before reaching the Feneng area so instead, careful bearings were taken to prominent peaks on the Il and Emuk Ranges, which were likely to be visible both from the Feneng area and from the south side at points whose positions were known accurately. With these and a latitude determination, the Feneng Base was fixed with reasonable accuracy. A base line was laid down in the clearing and from it a triangulation net was made of all other outstanding features visible. Individual traverses were then made by pace and compass methods using aneroid and hand level for heights.

A few traverses were made by Sadler and the author working together, but most of the exploration was carried out by each geologist working separately with his own carrying line in expeditions lasting up to eight days away from base.



3334/44.

[To face page 134.]

The party left the Feneng area January 27th, arriving back at the forward base on the south side of the Limestone Barrier January 30th, 1939.

Acknowledgments.

The author wishes to thank the Directors of Island Exploration Company Pty. Ltd. and Dr. K. Washington Gray, Chief Geologist, for permission to present this paper; Dr. M. F. Glaessner for his palaeontological determinations and helpful discussion; the Company staff at Kiunga Base Camp and the crew of Guinea Airways seaplane for their co-operation, and especially the late G. Sadler, E. Ross, R. Ely, and the Papuan natives who made up a most efficient and willing field party under very difficult and often hazardous conditions.

Physiography.

The area covered by this paper is that part of the southern slopes of the Central Highlands of New Guinea occupied by the headwaters of the Fly River. It is a region of sharp relief and mostly high elevation.

The Limestone Barrier rearing conspicuously along the foot of the Central Highlands in this area is divided into three sections, called from west to east, Il, Emuk, and Kaban Ranges. The Il and Emuk Ranges are separated by the Gim Gorge (Pl. V., figs 1 and 3) through which the Fly River leaves the mountains to commence its 590 miles run to the sea. The Gorge is a narrow cleft less than 2,000 feet wide at the top and 1,500 feet deep, diminishing practically to river level down dip some $6\frac{1}{2}$ miles downstream. A conspicuous though narrow air gap separates the Emuk from the Kaban Range. The three ranges present almost vertical cliffs, 1,500-2,000 feet high towards the north, but slope gently to the south. The highest point noted on the Il Range is about 4,400 feet, on the Emuk 5,700 feet, and on the Kaban Mt. Sari is about 7,000 feet.

The soft shales and sandstones immediately underlying the thick limestones have been much less resistant to erosion, and now constitute a wide stretch of low and subdued country at the base of the great limestone scarps, protected and modified by enormous talus slopes and residual blocks left by the receding scarps. The talus slopes and residual cover themselves have been modified by the tendency of the underlying shales to slump, the result being that they have assumed a low slope and possess a roughly mammilated surface at a distance from the scarps.

Below these soft strata the rocks are harder again, and becoming predominantly sandstones and conglomerates support high country in which has developed a series of conspicuous strike

ridges and dip slopes, the Melokin and Kuabgen being perhaps the most prominent (Pl. V., fig. 2). These constitute the southern limit of the Central Highlands proper. They are generally lowest where the Wok Feneng cuts through them in a gorge only a little less formidable than the Gim Gorge, and rise east and west outwards toward the divides with the Palmer and Aliee Rivers respeetively, where the relation of topography to geology becomes obscure. The Hindenburg Range comprising the eore of the Central Highlands in this area is nowhere less than 8,500 feet high, some peaks reaching 10,500 feet. The Kuabgen Range rises to a height exceeding 4,400 feet, while the most prominent point on the Melokin Range is 4,700 feet. Further south, Observation Hill on a well developed strike ridge is 2,830 feet, and on its counterpart west of the Wok Feneng a peak 3,100 feet high was observed.

The Feneng is undoubtedly the main stream, but the Bol and the Wunik are only a little less important as water earriers. All the large streams are rapid and turbulent, have steep-walled valleys and are more or less choked with great boulders. Near the Feneng Base Camp the Feneng is relatively quiet for a distance of about 2 miles upstream, the width is 200-300 feet, and although shallow a canoe can be used with difficulty; but downstream the gradient to the mouth of the Gim Gorge averages over 90 feet per mile in a series of cascades, the width reducing to 150-200 feet. Between the junctions with the Wunik and the Bol the gradient inereases from 60 to 110 feet per mile, width varying from 60 to 150 feet. Above Bol junction in the $2\frac{1}{2}$ miles traversed the river is a torrent falling at the rate of over 300 feet per mile and the stream is full of enormous boulders which almost bridge it in places.

A high terrace sloping downstream along the Feneng from just above Bol Junction where it is about 300 feet above present river level to near Base Camp where it falls to less than 50 feet indicates an earlier course of the stream. A series of soft horizontal thin bedded clays in the low country around the confluenee of the Feneng and its tributaries Kup and Ing and south of Base Camp suggests the existence of quite a considerable lake in perhaps the not very distant past, formed probably through a great landslide damming the mouth of Gim Gorge.

Despite the precipitous and sometimes almost vertical slopes, the whole country is clothed in dense jungle with the exception only of the small and relatively few native gardens, and a scrubby but tough vegetation on the top of sandstone ridges. Numerous conspicuous bare rock scars on the cliffs of the limestone ranges indicate the prevalence of large rock falls. Somewhat less conspicuous but still numerous are similar scars on the cliffs of the sandstone ridges.

The rocks are usually well exposed in the streams, but these are not always completely accessible and much physical effort is required to climb in and out of gorges to study exposures.

The shale members have suffered considerable slumping so that these rocks are frequently obscured. Particularly is this the case with the thick Feing mudstones in the main Feneng. Smaller streams, tributaries of the Wunik, provided the best sections in these strata.

Stratigraphy.

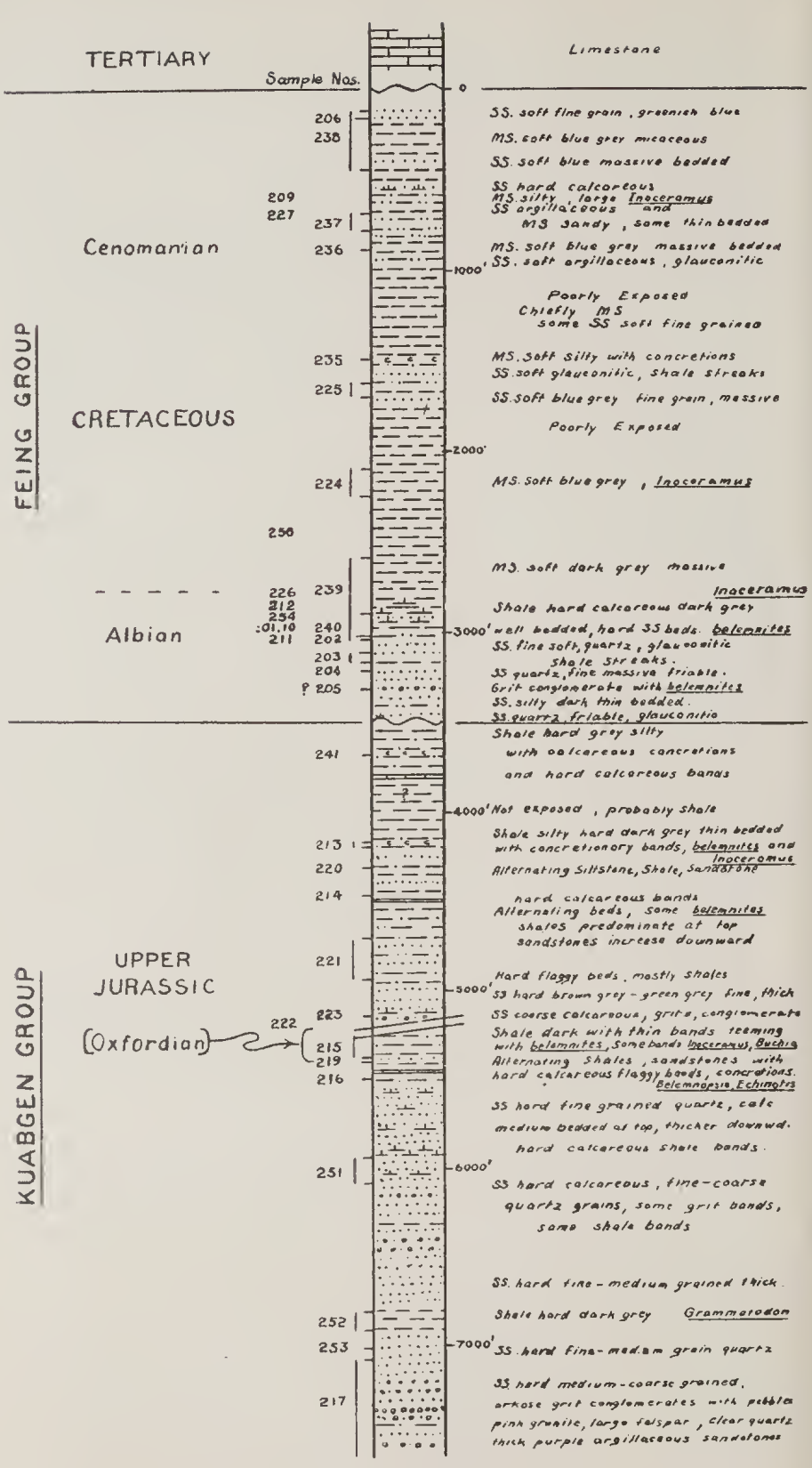
A thick section of marine sedimentary rocks totalling nearly 7,500 feet was found underlying the Tertiary limestones in the Feneng area. This section has been divided on lithological grounds into two distinct units of sedimentation named respectively Feing group and Kuabgen group. Both are dominantly argillaceous at the top and pass downwards into dominantly arenaceous strata, but the rocks of the lower Kuabgen group are slightly indurated and have a definitely older appearance.

Although the section is not very fossiliferous as a whole, *Inoceramus* and belemnites are fairly abundant in several widely scattered zones. Thus the age was recognized in the field as generally Mesozoic. Glaessner has examined the macro- and micro-fossils contained in the collected specimens and has assigned more specific age within the Cretaceous and Jurassic to the two lithological units. His determinations and conclusions are recorded in a paper entitled "Mesozoic Fossils from the Central Highlands of New Guinea," published simultaneously in these Proceedings.

The rock sample localities are shown on the accompanying geological map, and their position in the stratigraphic sequence on the columnar section for the Feneng area (fig. 1). This section illustrates the general character and thicknesses of the Cretaceous and Upper Jurassic sediments.

The contact between the Tertiary limestones and the Feing group has not been seen anywhere owing to the universal cover of talus at the foot of the great cliffs which mark the outcrop of these limestones everywhere in the Feneng area. However there is an abrupt and complete change in lithology and a big time break between them, the uppermost Cretaceous and the whole of the Eocene apparently being missing.

Chawner has reported the same situation in the Upper Palmer River some 20 miles east south-east, his Luap and Narin formations, sandstone and mudstone respectively, being almost identical in lithology, fauna and total thickness with the Feing group, while the Tertiary limestones from the two areas are also similar in character.



COLUMNAR SECTION for the FENENG AREA

FIG. 1.

However whereas Chawner postulates an angular unconformity between the Narin formation and the Kaban limestones, no evidence of an angular break was seen in the Feneng area. No actual contact was seen in the Palmer area either and the situation there was obscured also by faulting. In both areas the limestones appear to be underlain by the same Cretaceous formation, the close agreement in thickness and character between the Cretaceous sections exposed in the upper Palmer and the Feneng area suggesting that no persistent unconformity is present. Furthermore, wherever observed in the Feneng area the Feing mudstones appear to be dipping at about the same angle as the overlying limestones.

The evidence in the Feneng area suggests rather that the break between the Feing group and the Tertiary limestones represents chiefly a long period of non-deposition without appreciable folding or erosion.

Feing Group.

Extending from the foot of the great north-facing scarps of the H. Emuk, and Kaban Ranges to the lower slopes of the Central Highlands is a wide valley-like area whose subdued topography is in marked contrast with the high and rugged character of the remainder of the Feneng area. A covering of limestone talus and residual blocks occupies most of the surface, but many of the deeper streams have cut through it to expose a thick section of sediments, chiefly mudstones, dipping relatively gently toward the south. This subdued terrain is terminated northward by a prominent though not especially high standstone ridge which dips south beneath the mudstones.

Examination has shown that the mudstones grade downwards into the sandstones, the whole forming a sedimentary unit to which the name Feing group has been given—the Wok Feing being the stream in which the best section of the upper part was observed.

The whole series was not seen in one continuous section, but different parts of it are well exposed in the Wok Feing, Bok, Feneng, Kup and Ing, also in Descent Creek. From these it has been possible to work up a composite section. The total thickness so measured amounts to 3,400 feet minimum, part of the 200-250 feet of beds obscured by talus at the foot of the limestone cliffs no doubt belonging in the Feing group. This thickness is only an approximation, for outcrops showing dip are rare in the upper part owing to the prevailing massive character of the rocks, while their tendency to slipping and slumping on a large scale make even the best observations of dips a little uncertain.

The upper 2,800 feet, well exposed in the Wok Feing and the Wok Bok, are predominantly argillaceous consisting mainly of soft massive grey to blue-grey mudstones and silty micaceous mudstones, but with some thick zones of soft greenish-blue fine-grained sandy mudstones and argillaceous sandstones especially near the top. The sandstones are sometimes thick-bedded, sometimes thin-bedded, and often contain glauconite. Cone-in-cone limestone also is found on several horizons.

Towards the bottom the mudstones become darker, harder and more silty to consist largely of hard dark-grey to black silty shales, generally micaceous and frequently pyritic, medium to massive bedded and exhibiting spheroidal weathering with a yellow-brown ferruginous incrustation and giving off a strong sulphurous odour. Some of the beds are very calcareous, extremely hard and brittle.

Thin sandstone bands appear in these hard shales, becoming more important downward, and the section grades into argillaceous sandstones through a transition zone perhaps 100 feet thick.

The basal, dominantly sandstone, part of the group measures some 500 feet in the Wok Kup. No direct measurement was made in the Wok Bok because that stream plunges over a high waterfall in these rocks and is inaccessible, but from the elevation and dip the thickness would appear to be of the same order.

The sandstones are argillaceous at the top but less so downwards. The sand grains consist almost entirely of sub-angular to slightly rounded clear quartz, generally of fairly uniform size in individual beds. Glauconite is a common constituent throughout, distribution varying from even dispersion to scattered aggregation in pockets; occasionally it is so abundant as to give the rock a dark-green colour, often it is entirely absent. Thin beds of grey silty shale occur, particularly in the upper half of the sandstones. At some horizons thin grey shale streaks are conspicuous.

Bedding is generally medium to thick and mostly well defined. The strata are often fairly hard, especially at the top, with some very hard siliceous bands, but many of them are quite uncemented although tightly compacted and fall to pieces on being struck. There are also important zones of soft friable white sandstone consisting almost entirely of pure clear quartz especially towards the bottom.

Grain size is chiefly fine to medium becoming generally coarser downwards where there are some grits. Slightly waterworn pebbles of hard calcareous gritty conglomerate found in the Wok Kup downstream from the outcropping sandstones contain, in addition to abundant quartz and numerous belemnites, rounded

pebbles of hard calcareous shale and dark siliceous rock undoubtedly derived from the underlying Kuabgen group. These were not seen in place anywhere but it is believed they almost certainly come from somewhere in the basal Feing sandstones. A hard waterworn concretionary pebble containing canaliculate belemnites found among the stream pebbles at the same place is thought also to have been derived from the Kuabgen group by way of these conglomerates.

The Feing group generally is not visibly very fossiliferous. In the upper argillaceous part thin bands rich in large *Inoceramus* sp. were found in Descent Creek from a position high in the section, in the Wok Feing low in the section, and in the Woks Kup and Ing about the bottom. The mudstones contain also a fairly rich assemblage of foraminifera, which Glaessner (see p. 165) regards as establishing a Cenomanian age for the upper part of the Feing group.

In the Wok Feneng just above its junction with the Wok Wunik the belemnite *Parahibolites blanfordi* occurs fairly commonly in hard dark shales of the transition zone. Similar belemnites also were seen on about the same horizon in the Wok Ing. Foraminifera from this zone are regarded by Glaessner as indicating an Albian age.

No recognizable fossils at all were recovered from the basal sandstone formation, *in situ*, but weathered fragments of belemnites up to nearly an inch in diameter were found in the Wok Kup downstream from the outcropping sandstones. They occur among stream pebbles which included the belemnite bearing conglomerate mentioned above, some of the included belemnites being apparently the same as those found loose. Sandstone boulders with similar belemnites were observed in the Wok Ing adjacent to outcrops of lithologically similar rocks underlying the transition zone, but here again the fossiliferous deposits were not seen in place. Cylindrical holes resembling in shape and size the belemnites occurring loose in the Wok Kup, sometimes empty sometimes filled with hard clay, were observed in thin bands in the sandstones exposed in the Wok Kup fairly low in the section, and in the Woks Bok and Ing near the top. Possibly these cavities once contained belemnites, although these fossils generally seem to be more resistant than the containing strata.

In any case, as indicated previously, the belemnite bearing conglomerate is considered to have come from the basal sandstones of the Feing group. Unfortunately, while the belemnites in the conglomerates are well preserved, it has been impossible to extract them from the rock so that their features can be examined. For this reason Glaessner is unable to determine them, although he states that they have a Cretaceous rather than Jurassic aspect. Since the basal sandstones form a continuous series of strata with the transition zone which has been established as Albian, it is probable that they, too, are of that age, or very little older.

Thus the Feing group is referred to the middle Cretaceous, Cenomanian-Albian. The palaeontological sub-division of this group into Cenomanian and Albian agrees very closely with the lithological sub-division into an upper, dominantly mudstone, and a lower, dominantly sandstone, formation, except that the lithological basis would include in the upper part the hard dark shales at the top of the transition zone which however contain Albian fossils.

In thickness, fossils and general character, the Feing group is almost identical with the combined Narin and Luap formations described by Chawner from the upper Palmer River, the only difference being that the basal sandstones in the Palmer appear to be thicker though the bottom of the section was not reached, and that the transition zone appears to be thicker too, thus:—

Feneng Area.	Feet.	Upper Palmer.	Feet.
Feing group:		*Narin formation:*	
Upper, chiefly mudstone ..	2,800	Chiefly mudstone ..	2,125
Transition zone	100	*Luap formation:*	
Lower, chiefly sandstone ..	500	Transition zone ..	500
		Sandstone	825
	3,400		3,450

No contact between the Feing group and the underlying Kuabgen group was seen. However the Kuabgen group generally looks distinctly more indurated than the Feing, while the palaeontological evidence shows that there is a considerable time interval between the two groups, the uppermost Jurassic and much of the lower Cretaceous being absent. These points, together with the sharp lithological change from shales at the top of the Kuabgen to sandstones at the base of the Feing, with glauconite and gritty conglomerates containing weathered pebbles of the underlying Kuabgen group, suggest an erosional unconformity of some dimensions. In the Wok Wunik the Kuabgen shales are dipping at a higher angle than the overlying Feing beds where dips could be read; but as there is a gap of about 1,000 feet in which there are no outcrops and a still greater interval between exposures on which dips can be measured, while there is evidence in both units of increase in dip towards a maximum in the vicinity of the group boundary, this cannot be regarded as demonstrating an angular discordance. The general monoclinal conditions observed in the Feneng area give the impression that an angular divergence of no more than a few degrees at most can be expected.

Kuabgen Group.

The strata belonging to this group occupy the increasingly higher and more rugged country on the south flank of the Central Highlands. They support a number of high strike ridges, prominent among which are the Melokin and Kuabgen Ranges, the latter giving the group its name.

The upper part of the group is rather poorly exposed in the area visited and the section has been made up as a composite from outcrops inspected in the Woks Feneng and Wunik. The lower and greater part of the group however is exposed practically as one continuous outcrop in the Wok Feneng and the Bol River, which here flow through gorges not uniformly so high but almost as difficult of access as the Gim Gorge.

The highest beds seen lie about 100 feet below the top of the group and consist of hard grey silty micaceous shales with calcareous concretions, massive bedded at the top but becoming thinner bedded downwards with some very hard calcareous bands intercalated. These total about 250 feet in thickness and are followed by a gap of similar dimensions in which no outcrops were seen. Judging by the topography it is believed that this gap and also that at the top represent mainly argillaceous sediments. The next outcrops seen were hard dark-grey thin-bedded indurated-looking silty micaceous shales with hard concretionary bands and containing belemnites and *Inoceramus*. Below these are about 600-800 feet of beds, sometimes dominantly sandy, sometimes dominantly shaly, grey to greenish-brown in colour, thin to thick bedded, generally hard and often flaggy with frequent harder very calcareous bands; sometimes alternating hard sandstones, argillaceous sandstones and silty shales with some pyrite nodules. The shales often look indurated but the sandstones, though usually very hard, show no sign of alteration.

The sandstones increase in importance as the section is descended, becoming thicker and more numerous until there are some 250 feet consisting almost entirely of hard brownish-grey to greenish-brown fine grained sandstone, medium to thick bedded, with a thick hard calcareous coarse clear quartz sandstone including gritty bands containing some thick-shelled pelecypods, near the bottom.

At this stage the sequence is interrupted by structural complications in both the Wok Feneng and Wok Wunik, possibly 100-200 feet higher in the Feneng than the Wunik. In the Wok Feneng the monoclinal conditions are disturbed by two small anticlinal folds with associated faulting indicated by irregular dips and strikes, slickensides, breccias, calcite veins, and visible small faults. Similar manifestations of faulting are evident also in the Wok Wunik where, however, the traverse was not continued far enough to detect whether it is connected with folding.

No direct evidence was found to show the magnitude and nature of the faulting, but there is reason to believe that section is cut out rather than repeated, because a highly fossiliferous shale of peculiar appearance which occurs on the north side of the fault was not seen anywhere on the south side. Thus it is concluded, not very surely, that downthrow is to the south. However, the fossiliferous shale on the upthrow side is underlain by alternating

beds rather similar to those already described, suggesting that the same unstable conditions existed throughout the deposition of the strata now found on both sides of the fault, and therefore that the fault may be of relatively small dimensions.

The total thickness estimated for the upper part of the Kuabgen group is 1,710 feet with a thick coarse sandstone containing grit bands near the bottom. A conglomerate consisting of hard grey shale and sandstone pebbles in a fine sandy matrix observed in the fault zone in the Wok Wunik probably belongs here. Pebbles in this conglomerate resemble some of the hard calcareous shales and sandstones underlying the peculiar fossiliferous shales just mentioned, suggesting at least an interformational erosion interval. This, apart from the faulting, provides a convenient horizon for tentatively dividing the Kuabgen group into an upper and a lower part, the former being that already described.

The highest known member of the lower part is the above mentioned very fossiliferous shale adjacent to the fault in the Wok Feneng. A thickness of about 120 feet is exposed, with the top missing, consisting of relatively soft dark-grey shales, medium to thick bedded, silty and slightly micaceous at the top. A zone perhaps 20 feet thick near the bottom contains several thin bands teeming with fossils, some with belemnites, others with large *Inoceramus* and *Buchia malayomaorica*. (Sample 215.)

Below this are about 20 feet of greensands interbedded with grey to purple-grey shales containing pyrite, belemnites, ammonites, and pelecypods (sample 219); then about 100 feet of hard thin-medium bedded flaggy silty shales and fine grained sandstones, sometimes alternating; finally grading down into a thick sandstone formation, mostly fine grained at the top and becoming coarser downwards to finish as dominantly gritty arkose conglomerates some 900 feet thick, the lowest beds seen. There are several grit beds and shale bands interspersed through the sandstones, one important dark-grey shale member near the bottom being 110 feet thick and containing *Inoceramus*.

The conglomerates are hard, cemented, well consolidated, and generally massive bedded, consisting principally of angular to sub-angular clear quartz fragments with sub-angular pebbles up to 8 inches through of coarse pink granite with clear quartz and large pink felspars, some pink felspar and rare small well rounded pebbles of grey quartzite and hard grey sandstone. There are many thick beds of grey argillaceous sandstone which weather purplish and constitute the vehicle for numerous immense landslides, especially along the Bol River the north bank of which is really a great dip-slope whose foundations are being eroded away continuously by the swift waters of the Bol.

The total thickness of the lower Kuabgen is 2,330 feet minimum, making a total for the group of 4,040 feet observed, with an unknown amount of section missing through faulting and the

base not having been reached. The Wok Feneng was traversed with greater and greater difficulty upstream until what seemed like a definite reversal in dip was encountered. Subsequent observations from Kuabgen Range indicated that this was not the case and that no more than a small local fold occurs there. However, at the point reached the gradient of the stream exceeds 300 feet per mile and no pebbles were found other than the sandstones and conglomerates already known. Consequently it is considered that very little if any more section is exposed in the Feneng, and at any rate nothing below the conglomerate outcrops there.

The Kuabgen group is even less fossiliferous generally than the Feing group, but macro-fossils are visible on several horizons. Belemnites were seen in two zones in the upper part, both in the Wok Feneng; one from dark-grey flaggy argillaceous siltstone or fine sandstone about 1,000 feet down in the section, the other from hard dark thin bedded shale containing concretions, about 400 feet higher, where they are associated with *Inoceramus*. Glaessner has determined the belemnite from the latter outcrop to be *Belemnopsis gerardi*.

As mentioned previously a shale band about 20 feet thick in the upper part of the lower Kuabgen group contains thin very richly fossiliferous layers. One of these is teeming with belemnites recognized by Glaessner as *Belemnopsis gerardi*, another is practically built up of pelecypods which he considers are *Buchia malayomaorica* with some large *Inoceramus* sp. Immediately underlying are alternating beds one of which, a pyritic concretionary greensand, contains *Belemnopsis* cf. *indica*, *Meleagrinella braamburiensis* and a few indeterminate ammonites.

The thick shales towards the bottom of the exposed section contain *Grammatodon* (*Indogrammatodon*) *virgatus* and a few *Inoceramus* sp.

Glaessner considers that the palaeontological evidence demonstrates an Oxfordian age for the *Buchia-Belemnopsis* beds and a possibly Callovian age for the underlying *Echinotis* and *Grammatodon* beds, making the Kuabgen group generally Upper Jurassic.

Since the base of the Kuabgen group has not been reached anywhere in this part of New Guinea, there is no direct evidence of the character of the immediately underlying rocks. However, since the lowest strata seen consist almost entirely of a considerable thickness of fresh looking and only slightly rounded granite derivatives which become coarser grained as the section is descended, it is believed that the granite surface which furnished these sediments was situated near-by and that in all probability granite basement underlies the Kuabgen conglomerates at no great depth.

This situation occurs in the Chimbu area, some 250 miles to the east, where Noakes (1939) reports that a very thick section of Mesozoic rocks rests directly on granite, palaeontological examination setting the age of the basal sediments at Upper Jurassic.

Igneous Boulders.

Numerous well rounded pebbles and boulders of a dense igneous rock with large augite or hornblende crystals in a light-grey ground mass, possibly andesitic, occur in the Bol River and further down in the Wok Feneng. The source of the boulders was not found but as they do not occur as components of any of the sedimentary rocks in the area, it is inferred that they come from dykes in the upper Bol valley.

Notes on Mesozoic Geological History.

Mesozoic rocks are known from a number of widely scattered points in New Guinea, principally along the Central Highlands. These occurrences have been listed by Glaessner (1943) who has discussed their correlation. He suggests that in Jurassic times, part of western and central New Guinea was a geosynclinal area which extended possibly into eastern New Guinea.

The information generally is very scanty, a big proportion of the occurrences being known only from stream pebbles and very few good sections having been inspected. Most of the information so far obtained is barely sufficient to give an idea of distribution, and provides little basis for deductions concerning geological history.

Although still meagre, more is known perhaps of that part of the Central Highlands which includes the Feneng area than of any other region in New Guinea.

Data presented in this paper indicate that the oldest Mesozoic sediments seen in the Feneng area, arkose conglomerates grits and sandstones of the lower Kuabgen group, Callovian in age, in all probability lie very close to granite basement. In the Feneng region generally, Callovian fossils have been reported from the Strickland River about 50 miles south-east of the Wok Feneng, from the Sepik River about 50 miles north, and from the Digoel River 70 miles north-west. Pre-Callovian also has been reported from the Strickland.

The character of the lower Kuabgen group suggests that the immediately adjacent land surface had been eroded down to granite basement prior to the beginning of Kuabgen deposition. Hence it seems likely that the Feneng area itself was dry land during most of lower Mesozoic times at least. The distribution of Upper Jurassic rocks in the region suggests that a Mesozoic geosyncline was developed mainly north of the Feneng area and

that the granite land mass which provided the lower Kuabgen sediments lay to the south and south-west, possibly connected with the Australian shield.

The subsidence which initiated the Upper Jurassic marine transgression in the Feneng area did not continue uniformly, fluctuations in rate of subsidence being denoted by irregular alternations in lithology, especially of the middle to upper Kuabgen deposits. The conglomerates at the base of the upper Kuabgen group are evidence of at least one important oscillation which raised the lower Kuabgen sufficiently to undergo erosion.

There is a big gap in the Feneng record between Oxfordian and Albian, the lowermost Cretaceous and possibly the uppermost Jurassic being absent. Representatives of some of the missing stages have been reported from the Sepik River, the Om and the Strickland. Possibly uplift of the southern marginal area of the geosyncline during the early Cretaceous at least, favoured denudation of whatever post-Oxfordian strata may have been deposited, before renewed submergence in Albian time started deposition of the Feing group.

Waterworn pebbles of Kuabgen type occurring in the basal Feing sandstones indicate some erosion of the Jurassic strata, while the general quartz sandstone nature of these basal beds, with frequent subangularity of grains, indicates that once again a granite land area was the principal source of the sediments. This idea is supported also by the abundant glauconite in the Feing group.

Subsidence seems to have been more uniform and widespread in the upper Feing, resulting in the basal sandstones grading into mudstones which persisted, with relatively minor intercalations of sandstone, through a considerable thickness of strata and occupying at least a large part of Cenomanian time.

Another big time gap occurs between the Cenomanian and Tertiary. Here there is some slight evidence of a long period mainly of non-deposition. Possibly during this period major regional subsidence resulted in this area being covered by deep water far removed from land and in which conditions were not favourable to abundant marine life.

A striking feature of the whole Mesozoic section in the Feneng area is the universal prevalence in the sandstones and grits of clear quartz grains, most frequently only partially rounded. There seems to be little doubt that the Feing and Kuabgen groups were derived almost entirely from a granitic source, with relatively minor amounts of material eroded from already deposited Mesozoic sediments.

As indicated above, the Feneng area appears to have been located about the southern margin of an Upper Mesozoic geosyncline with a granite land surface extending to the south and south-west. The absence of any appreciable angular discordance